

LG vs. Samsung Smart TV: Which Is Better for Tracking You?

SANE(Security Analysis aNd Evaluation) Lab

Korea University(高麗大學校)

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Who are we?

Sangmin Lee (李相旼)

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Sangmin Lee is a master student of SANE(Security Analysis and Evaluation) Lab on CIST(Center for Information Security Technologies) at Korea University. He is most interested in offensive security about system vulnerabilities and is interested in fields such as digital forensics, security assessment, and software testing. Also, he participated in projects such as "Security Testing for External Interfaces of Vehicular Wireless Systems", "Cyber Fast Track related to IoT devices vulnerabilities analysis" and "WebOS smart TV international security CC(Common Criteria) certification acquisition." In 2015, he participated as a mentee at BoB(Best of the Best), an information security leader training program hosted by KITRI(Korea Information Technology Research Institute). He, in BoB, conducted a project to analyze vulnerabilities in embedded devices such as routers, IP cameras, Smart home, and SCADA. Also, he presented the project results at POC(Power Of Community) 2015 on the subject of "What if Fire Sale occurs in Korea?"



Who are we?

Minsu Park (朴珉洙)

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Facebook : @bucktae

Minsu Park received his B.S degree in Computer Network from Silla University of Korea, in 2010 and also received his M.S degree in Information Security from Korea University of Korea, in 2013. He is currently working toward the Ph.D. degree in Information Security, Korea University, Korea. His research interests include Information Assurance, IoT Security, Digital Forensics and Usable Security.



Seungjoo Gabriel Kim* (金昇柱)

*Corresponding Author

E-mail: skim71@korea.ac.kr

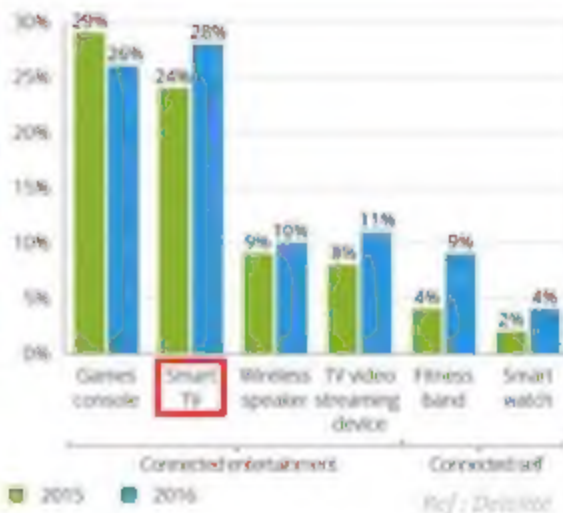
Homepage : www.kimlab.net

Facebook, Twitter : @skim71

Prof. Seungjoo Gabriel Kim is a full professor of Undergraduate Department of Cyber Defense / Graduate School of Information Security in Korea University, a member of CIST(Center for Information Security Technologies) of Korea University, a vice-director of CW-TEC(Cyber Weapon Test and Evaluation Center) of Korea University, a head of SANE(Security Analysis and Evaluation) Lab, an advisor of 'CyKor'(Cyber security club at Korea university), a founder/advisory director of a hacker group, 'HARU' and an international security & hacking conference, 'SECUINSIDE'. Prior to joining a tenure-track faculty member at Korea University in 2011, he was previously an Assistant & Associate Professor of School of Information and Communication Engineering in Sungkyunkwan University for 7 years ('04-'11). Before that, he worked as a Team Leader of Cryptographic Technology Team and (CC-based) IT Security Evaluation Team of KISA(Korea Internet & Security Agency) for 5 years ('98-'04). He received his B.S. ('94), M.S. ('96), and Ph.D. ('99) in Information Engineering from Sungkyunkwan University, Korea.



The History of Digital Forensics on Smart TV



The History of Digital Forensics on Smart TV

"That Time Cops Searched A Samsung Smart TV For Evidence Of Child Abuse"

- US Forbes magazine in 2017.

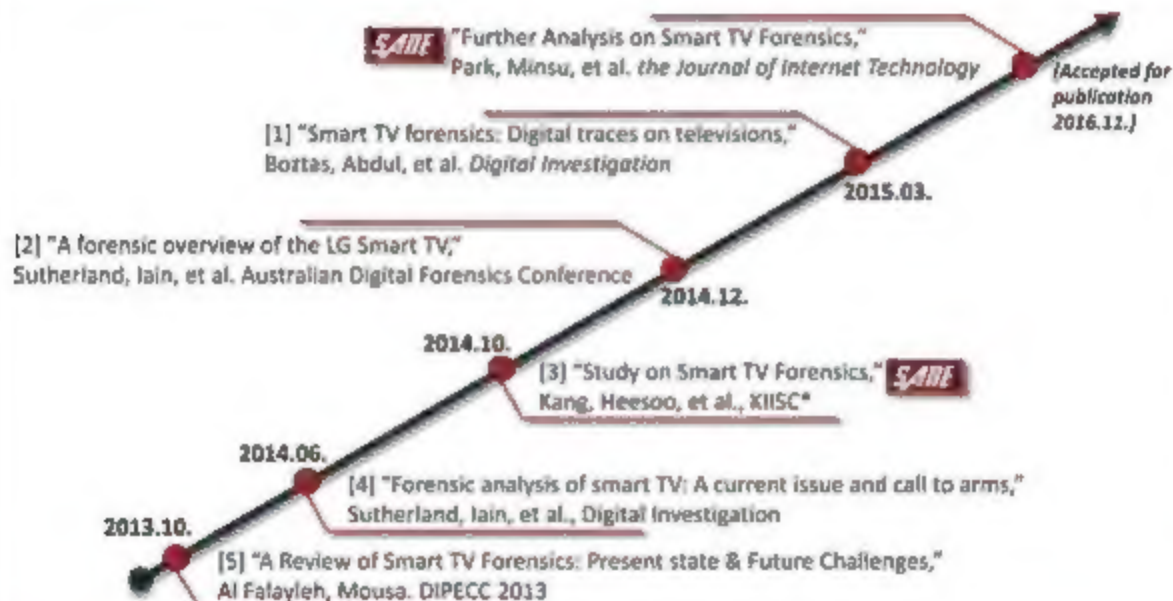
It occurred in June 2016, when San Diego officers working for the Homeland Security Investigations (HSI) unit sought information from the Samsung smart TV of Mikhail Feldman, a man previously convicted for possession of "images of minors engaged in sexually explicit conduct," as outlined in an affidavit for

7. Probation officers also found several items of contraband and evidence of
conduct violating the terms of Feldman's supervised release. These items include
a Samsung Smart Television (with internet access), Model: UN46F6350AF,
Serial No: Z6PRJCVDA03513D, a Toshiba Satellite laptop, Model: PSAFGU,

▲ it appears to be the first ever published warrant for a smart TV

The History of Digital Forensics on Smart TV

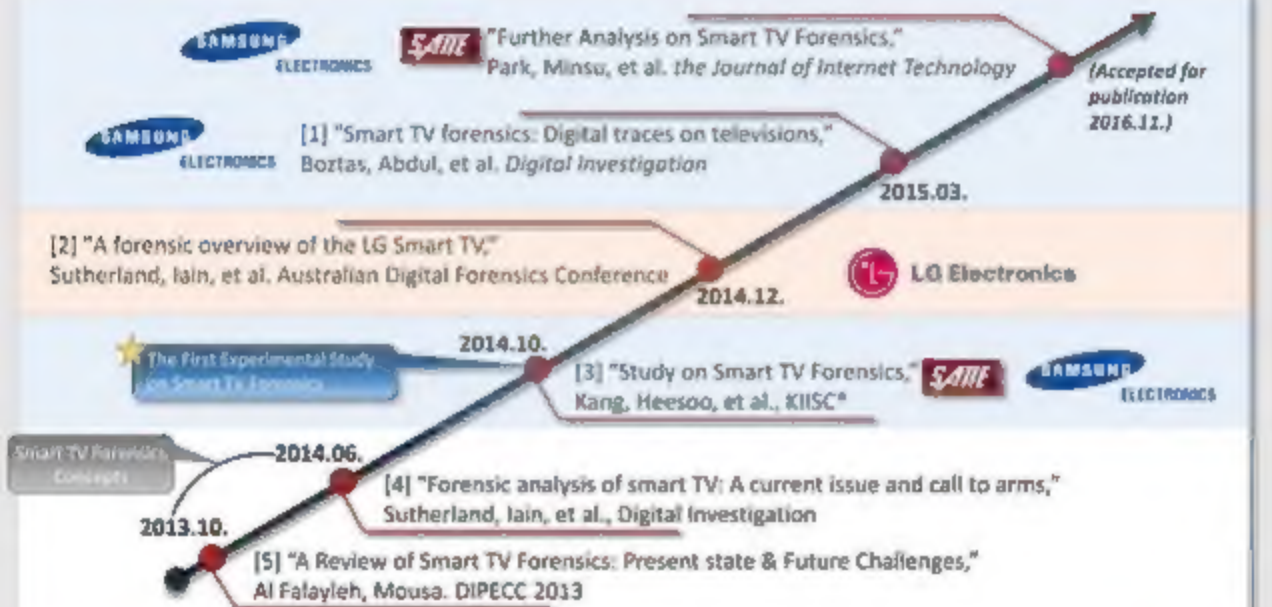
Related works on Smart TV Forensics



*KIISC : Korea Institute of Information Security & Cryptology

The History of Digital Forensics on Smart TV

Related works on Smart TV Forensics



*KIISC : Korea Institute of Information Security & Cryptology

The History of Digital Forensics on Smart TV



[5] "A Review of Smart TV Forensics: Present state & Future Challenges,"
Al Falayleh, Mousa., DIPECC 2013

(1) Digital evidences on the Smart TV



(2) Challenges facing the Smart TV forensics

- Currently, Smart TV is continuously developed
- Can't use existing forensics tools on the Smart TV

[4] "Forensic analysis of smart TV: A current issue and call to arms,"
Sutherland, Iain, et al., Digital Investigation

(1) Data acquisition method on the Smart TV

Smart TV uses the
soldered storage device



1. Relevant digital clues
2. Universality of methods and techniques
3. The availability of assistance from the industry
4. The need for specialist knowledge or equipment

The History of Digital Forensics on Smart TV



Target



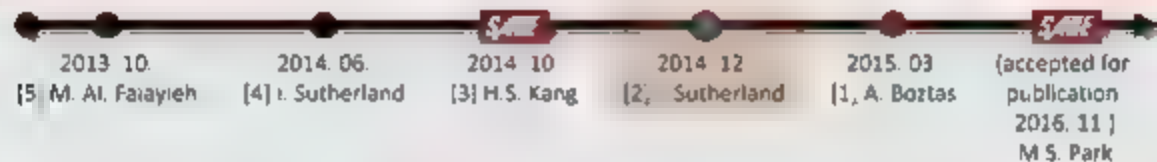
Samsung
UN46ES8000(2012)

Analysis Process



-> Collecting 9 User's Action Data on Features of TV & Applications

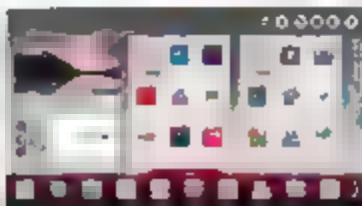
The History of Digital Forensics on Smart TV



Target



LG
42LSS70T ZB(2012)



LG
55LA740V(2013)

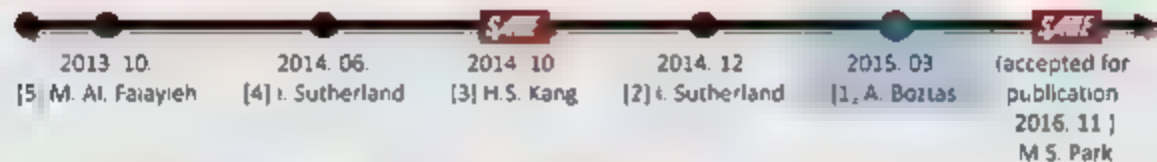
Analysis Process



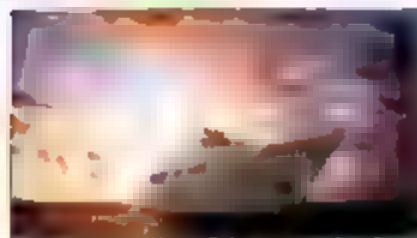
-> Collecting 10 User's Action Data on TV & Applications Menu

(e.g. Recent History . *My Apps* > *Home* > *Recent*)

The History of Digital Forensics on Smart TV

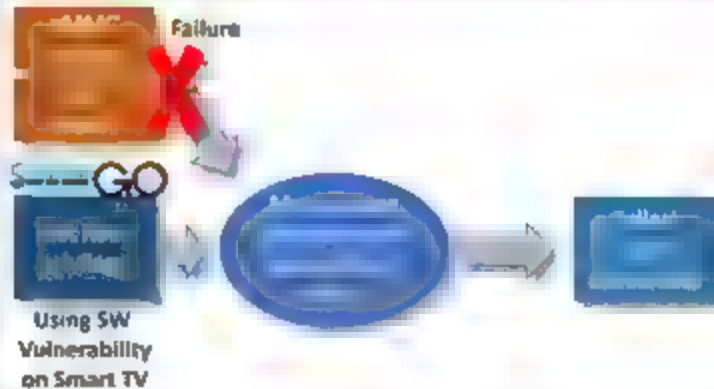


Target



Samsung
UE40F7000SLXXN(2013)

Analysis Process



-> Collecting about 8 User's Action Data on Features of TV & Applications

The History of Digital Forensics on Smart TV



Target



Samsung
UN46ES8000(2012)

Compare with the previous studies



The History of Digital Forensics on Smart TV

M Al Farayieh [5]		16 Smart TV [2]	A. Boxer [1]		
2013	2014	2014	SAFE [3]	2015	SAFE [3]
DIPECC 2013	Digital Investigation	Australian digital forensics confer	KIISC*	Digital investigation	The journal of internet Technology
		42L5570T ZB, S5.A74QV	UN46E58000	UE40F7000S, JCKM	JN46E58000
		2012 2013	2012	2013	2012
		webOS 2.0	Proprietary OS	Proprietary OS	Proprietary OS
		Failed to acquire data	Software Vulnerability (1-day vuln)	Software Vulnerability (1-day vuln)	Software Vulnerability (1-day vuln)
		Using only TV's functions (config menu, app info)	(1) Disk Imaging (2) Drilling	(It is guessed in the same way as us)	(1) Disk Imaging (2) Drilling

*KIISC Korea Institute of Information Security & Cryptology

The History of Digital Forensics on Smart TV

Smart TV Hacking

LG Smart TV

Hack In Paris 2017

"Are you watching TV now? Is It real? Hacking of smart TV with 0-day"



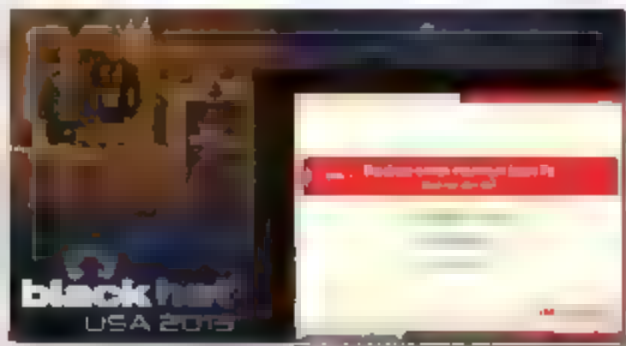
The History of Digital Forensics on Smart TV

Smart TV Hacking

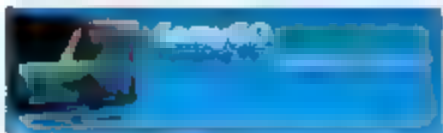
Samsung Smart TV

Black Hat USA 2013

▼ "Hacking, Surveillance, and deceiving victims on Smart TV" ▼ "The Outer Limits: Hacking A Smart TV"



Online community on the Samsung TV Firmware ►

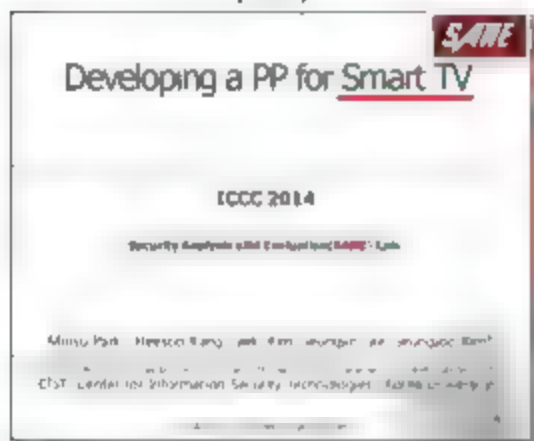


The History of Digital Forensics on Smart TV

Common Criteria on the Smart TV

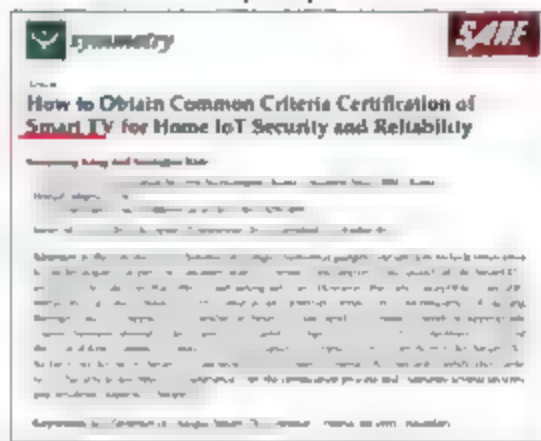
LG Smart TV

Study a PP(Protection Profile) for Smart TV
(2014)



LG Smart TV

How to obtain CC Certification of Smart TV
(2017)

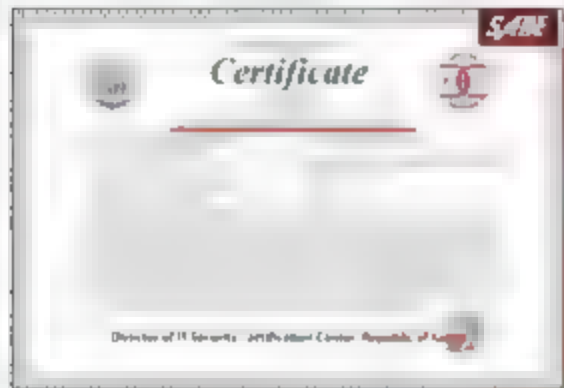


The History of Digital Forensics on Smart TV

Common Criteria on the Smart TV

LG Smart TV

LG Smart TV Application Security Solution
(received CC EAL2 certification)



Samsung Smart TV

Samsung Smart TV Security Solution
(received CC EAL1 certification)



LG webOS 3.0 Smart TV Forensics

- Data Acquisition**
- File System & Data Analysis**
- Collect LG Smart TV's digital evidences**

Target LG webOS 3.0 Smart TV



- Model : 43UH6810
- OS : webOS 3.0
- Firmware : 4.30.85 (17 04.19)
(Latest version is updated
on 17 10.28)

What is webOS?



LG



- webOS is a mobile operating system acquired by HP for use in various products manufactured by LG
- LG announces products that use webOS at CES every year
- Currently, Smart TV, SmartWatch(Urbane), and Refrigerator produced in LG have used the webOS.

LG webOS 3.0 Smart TV Forensics

- Data Acquisition

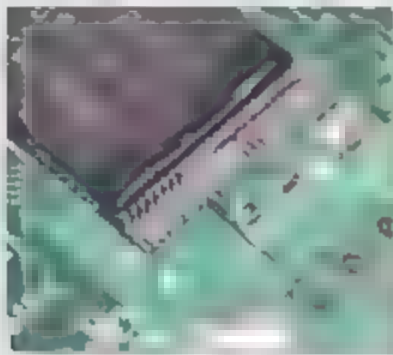
The System (OS) Data Acquisition

Content (OS, Apps, etc.) Data Acquisition

Data Acquisition

Invasive Physical Data Acquisition

- But, Smart TV uses soldered storage devices & Disable JTAG, UART port



> **laborious work**

(In general, Smart TV's cost over \$1000.)

=> Data Acquisition through application vulnerabilities

Data Acquisition

Using application vulnerability to acquire data

Obtain accessible
privilege to filesystem

Unknown Vulnerabilities (0-day)



IDA Pro

by Ilfak Gouffar



EBUGGER

\$ gdb



Known Vulnerabilities (1-day)



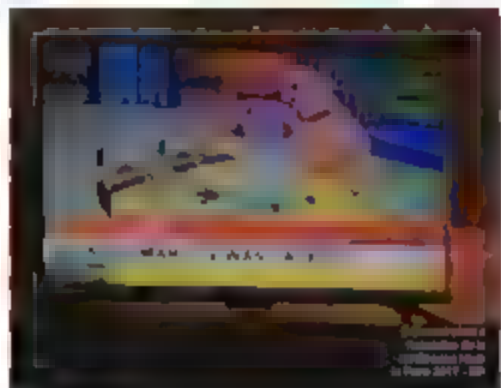
**EXPLOIT
DATABASE**



Data Acquisition

Hack In Paris 2017 – LG webOS Smart TV's 0-day

"Are you watching TV now? Is It real?. Hacking of smart TV with 0-day"



Attack Vector



- webOS emulator for developers

- 1) Connect to TV's SSH services
- 2) Remote app installation on TV
- 3) Remote app execution
- 4)

Connection to TV through SSH

```
SANGMIN@i-MacBook-Pro:~$ sudo su
SANGMIN@i-MacBook-Pro:~$ export PATH=$WEBOS_CLI_TV:$PATH
SANGMIN@i-MacBook-Pro:~$ arec-novacom -d tv1 -r "sh"
id
uid=6811(prisoner) gid=5000 groups=29(audio),44(video),505(compositor),509(se),777(c
rashd)
ls -al
total 40
drwxrwxrwx  4 root    root          4096 Nov  7 18:28 .
dr-xr-xr-x  5 prisoner 5000         4096 Jul 13 01:18 ..
drwxrwxrwx  2 develop develop     4096 Oct 31 14:13 ssh
drwxrwxrwx  3 root    root          4096 Oct 31 14:29 apps
prwxrwxrwx  1 prisoner 5000           0 Nov  7 18:17 backpipe
rwxrwxrwx  1 prisoner 5000           87 Oct 31 14:22 cmd
-rwxrwxrwx  1 5839     5000        13195 Oct 31 14:13 jail_app.conf
-rwxrwxrwx  1 5839     5000        1631 Oct 31 14:13 jail_app.conf.sig
lrwxrwxrwx  1 root    root          18 Oct 31 14:13 log -> /tmp/developer/log
mount
mount | wc -l
0
```


Data Acquisition

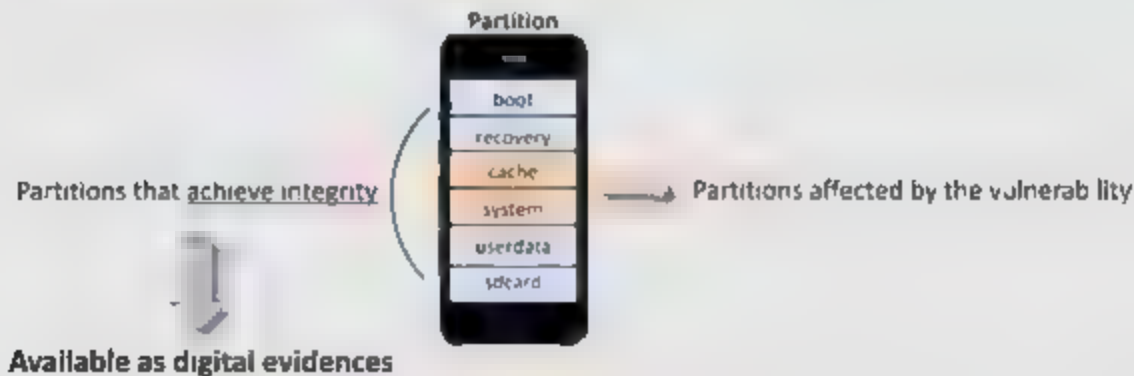
Obtain root privilege with Command Injection

```
msf5nullgasmf5null-virtual-machine:~$ nc -nvlp 31337
Listening on [0.0.0.0] (family 0, port 31337)
Connection from [192.168.0.12] port 31337 [tcp/*] accepted (family 2, sport 48736)
id
uid=0(root) gid=0(root) groups=0(root),10(wheel),500(pulse-ecsd),500(ss),777(crashd)
id
uid=0(root) gid=0(root) groups=0(root),10(wheel),500(pulse-ecsd),500(ss),777(crashd)
mount | nc -l
115
```

Data Acquisition

How can achieve the integrity of original data when data is acquired via rooting?

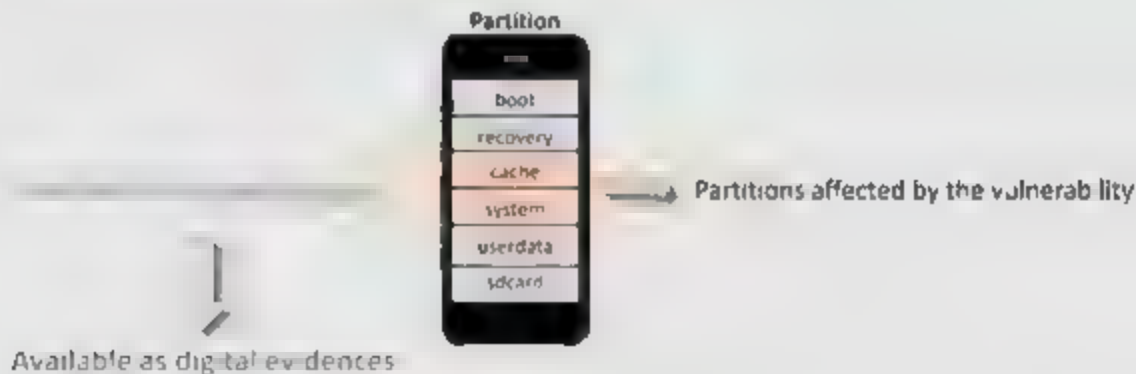
e.g. Smartphone's Digital Forensics



Data Acquisition

How can achieve the integrity of original data when data is acquired via rooting?

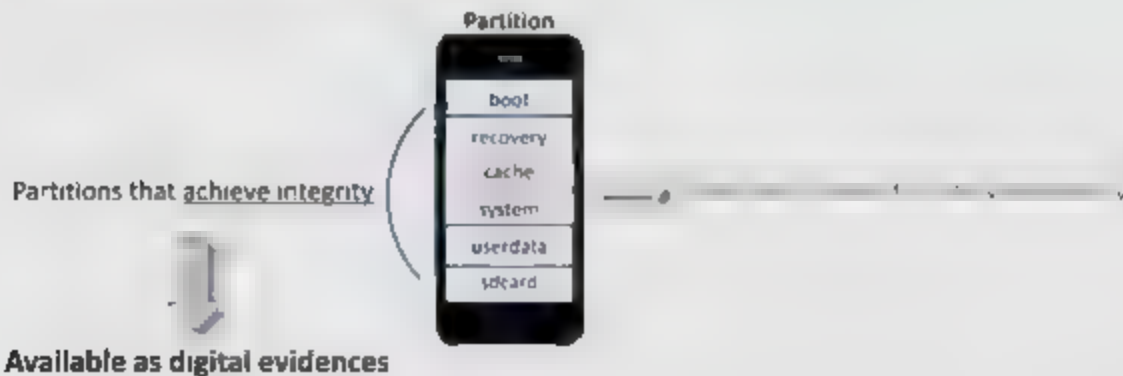
e.g. Smartphone's Digital Forensics



Data Acquisition

How can achieve the integrity of original data when data is acquired via rooting?

e.g. Smartphone's Digital Forensics



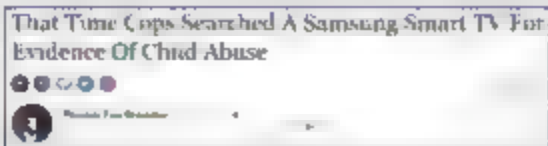
How can achieve the integrity of original data when data is acquired via rooting?

In case of Smart TV,

- ① The use of partitions is ambiguous. Therefore, the vulnerability affects most partitions.
(It is corresponding to not only our study but also existing studies)
- ② Integrity can be considered on a folder-by-folder basis, not a partition.

So, I think...

as in the case of the United States, there will be a social debate on using a vulnerability to acquire original data against smart TV as the need for smart TV forensics increases.



LG webOS 3.0 Smart TV Forensics

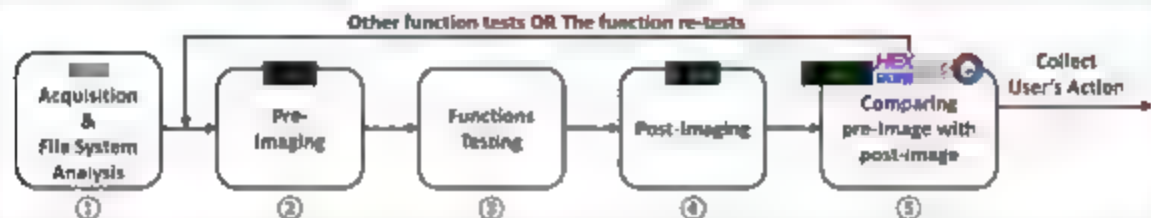
- File System & Data Analysis

Data Analysis – File System

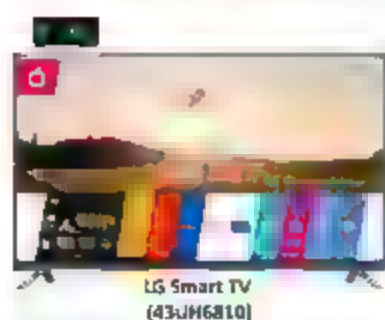
Partition	Path	File system
/dev/mmcblk0p15 /dev/mmcblk0p35		
/dev/mmcblk0p50	/mnt/lg/db8	ext4
	/var/db	ext4
/dev/mmcblk0p51	/home	ext4
	/mnt/lg/cmn_data	ext4
	/mnt/lg/flash/data	ext4
	/mnt/lg/user	ext4
	/var	ext4
	/mnt/lg/cache/flash	ext4
	/mnt/lg/cache/sdp	ext4
	/mnt/lg/cache/browser	ext4
	/mnt/lg/cache/webbrowser	ext4
	/var/palm/jai/com.webos.app.browser/var/luna/preferences	ext4 (read only)
	/var/palm/jai/com.webos.app.browser/mnt/lg/cache/webbrowser	ext4
	/var/palm/jai/com.webos.app.browser/mnt/lg/cmn_data/admanager/cache	ext4 (read only)
/dev/mmcblk0p52	/mnt/lg/appstore	ext4
	/media	ext4
	/var/palm/jai/com.webos.app.browser/media/internal	ext4

Data Analysis

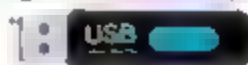
Process of Data Analysis



Smart TV's Disk Imaging Environment



- (1) Connect to ssh of TV with root perm
- (2) Upload image.py scripts through tftp & execute
- (3) Disk image on `.../usb/sda/sda1/[images].[time].dd`



- (4) Sending Image file
& `$ rm .../usb/sda/sda1/*`

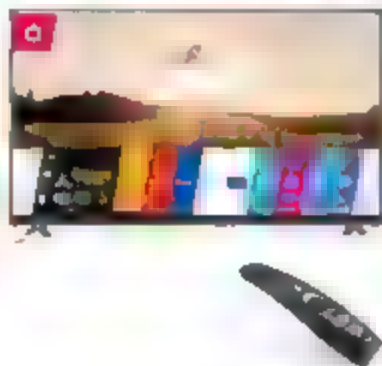


Example) Steps ② ~ ④ - Disk Imaging & Testing

② Pre-Imaging

```
before mmccolkip 5 70 0" 3 0 38 dd
before mmccolkip 20 20 4 0 4 00
before mmccolkip 11 20 0 0 38 50
before mmccolkip 12 10 0 0 38 dd
before mmccolkip 0 20 0 0 5 00
before mmccolkip 20 0 0 0 39 00
before mmccolkip 0 0 0 0 38 dd
before mmccolkip 20 0 0 0 38 dd
before mmccolkip 5 0 0 0 39 dd
before mmccolkip 50 20 0 0 49 dd
before mmccolkip 20 0 0 0 45 dd
before mmccolkip 20 0 0 0 50 00
```

③ Functions Testing



④ Post Imaging

```
after mmccolkip 20 0 0 0 40 48 dd
after mmccolkip 20 0 0 0 40 49 dd
after mmccolkip 25 20 0 0 40 47 dd
after mmccolkip 20 20 0 0 40 47 dd
after mmccolkip 20 0 0 0 40 49 dd
after mmccolkip 20 0 0 0 40 49 dd
after mmccolkip 20 0 0 0 40 48 dd
after mmccolkip 20 0 0 0 40 48 dd
after mmccolkip 20 0 0 0 40 49 dd
after mmccolkip 20 0 0 0 40 50 dd
after mmccolkip 20 0 0 0 40 55 dd
after mmccolkip 20 0 0 0 40 00 dd
```

Example) Step ⑤ - Compare Pre-Image with Post-Image (diffing)

(1) `$ diff -rNd ~/pre_image ~/post_image`

(2, Using Beyond Compare - Windump to binary diffing

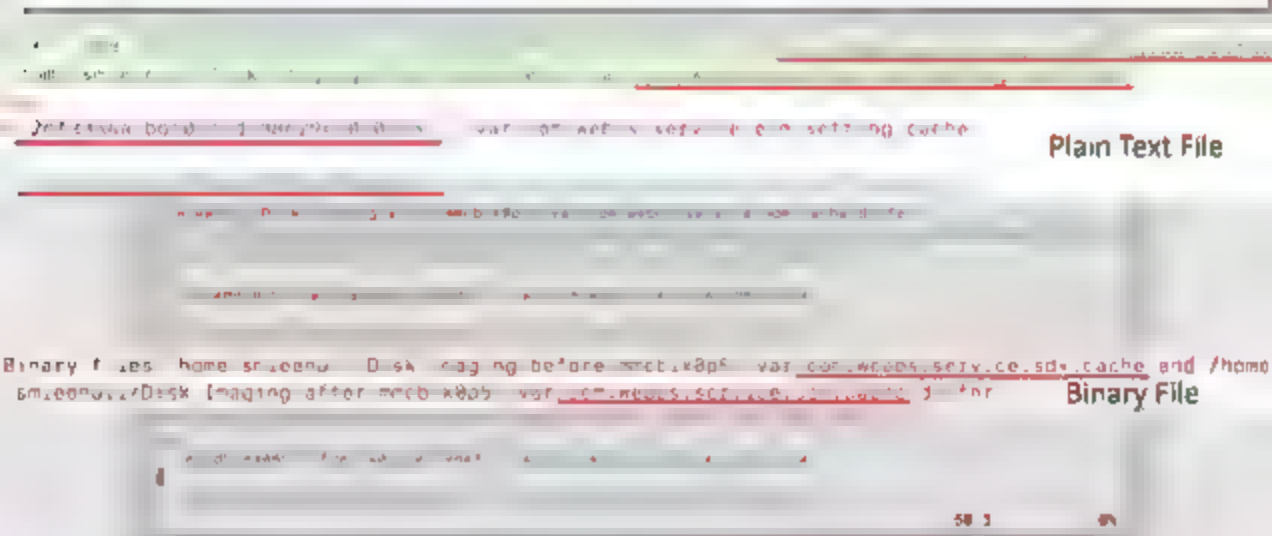


Data Analysis

Example) Step ⑤ - Compare Pre-Image with Post-Image (diffing)

```
(1) $ diff -rNd ~/pre_image ~/post_image
```

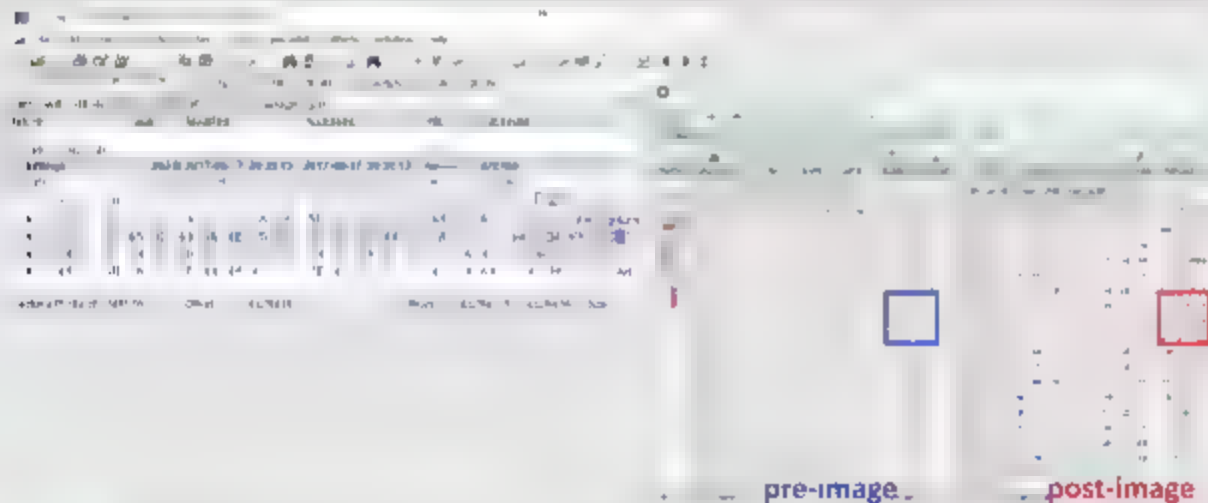
12. Using Beyond Compare WinHex to binary diffing



Example) Step ⑤ - Compare Pre-Image with Post-Image (diffing)

(1) \$ diff -rNd ~/pre_image ~/post_image

(2) Using Beyond Compare, WinHex to binary diffing



LG webOS 3.0 Smart TV Forensics

- Collect LG Smart TV's digital evidences

Collect LG Smart TV's digital evidences

12 User's Actions

(First check 18 July 2017, Last check 14 Oct 2017)

#	User's Action	Path
1	Last TV On-time	/mmcbkup50/wardb/main/LOG
2	TV Channel List	/mmcbk0p51/epg/db/PBS_OFF_08_0_4.db /mmcbk0p51/epg/tuner_favorite_move_index.txt
3	External Storage Usage History	/mmcbk0p52/cryptofs/data/db8/mediadb/media/*.log
4	TV ON/OFF Reservation	/mmcbk0p51/var/luna/preferences/time
5	Hardware Connection Information	/mmcbk0p51/var/lib/webappmanager3/LocalStorage/file_com.webos.app.inputmgr_0.localstorage
6	Installed App Information	/mmcbk0p52/cryptofs/apps/usr/lib/pkg/status
7	Internet History	/mmcbk0p51/webbrowser/chrome/Default/Bookmarks, Prefer*, History
8	Recently Service Usage History	/mmcbk0p52/cryptofs/data/db8/mediadb/media/*.log
9	App Install History	/mmcbk0p51/var/luna/data/downloadhistory.db
10	Checking Captured Image	/mmcbk0p52/captureTV
11	Last time app opened	/mmcbk0p51/var/lib/webappmanager3/LocalStorage/https_kr.igrecommends.lgappstv.com_0.localstorage
12	Connected Wifi Information	/mmcbk0p51/var/lib/connman/*

Collect LG Smart TV's digital evidences

12 User's Actions

(First check 18 July 2017, Last check 14 Oct 2017)

#	User's Action	Path
1	Last TV On time	/mmcbk0p50/var/db/main/LOG
2	TV Channel List	/mmcbk0p51/epg/db/PBS_Off_DB_0_4.db /mmcbk0p51/epg/tuner_favorite_move_index.txt
3	External Storage Usage History	/mmcbk0p52/cryptofs/data/db8/mediadb/media/*.log
4	TV ON/OFF Reservation	/mmcbk0p51/var/luna/preferences/time
5	Hardware Connection Information	/mmcbk0p51/var/lib/webappmanager3/LocalStorage/file_com.webos.app.Inputmgr_0.localstorage
6	Installed App Information	/mmcbk0p52/cryptofs/apps_usr/lib/pkg/status
7	Internet History	/mmcbk0p51/webbrowser/chrome/Default/Bookmarks, Prefer*, History
8	Recently Service Usage History	/mmcbk0p52/cryptofs/data/db8/mediadb/media/*.log
9	App Install History	/mmcbk0p51/var/luna/data/downloadhistory.db
10	Checking Captured Image	/mmcbk0p52/captureTV
11	Last time app opened	/mmcbk0p51/var/lib/webappmanager3/LocalStorage/https_kr.igraecommends.lgappstv.com_0.localstorage
12	Connected Wifi information	/mmcbk0p51/var/lib/connman/

Collect LG Smart TV's digital evidences

#	User's Action	Path
1	Last Tv On time	/mmcbk0p50/var/db/main/LOG

```
016,01,01 09:00:10.210000 751ba000 Recovering log
2016/01/01 09:00:35.223000 751ba000 Level-0 table
2016/01/01 09:00:36.232000 751ba000 Level-0 table
2016/01/01 09:00:36.240500 751ba000 Index type-1
2016/01/01 09:00:36.248500 751ba000 Index type-1
2017/02/12 20:34:36.052000 730ff450 Novel 0130
2017/02/12 20:34:36.213000 730ff450 Compacting log > 30K files
2017/02/12 20:34:37.040000 730ff450 Generated table
2017/02/12 20:34:37.750000 730ff450 Generated table
2017/02/12 20:34:37.800000 730ff450 Generated table
2017/02/12 20:34:37.800000 730ff450 Compacted log > 30K files
2017/02/12 20:34:37.800000 730ff450 compacted log files[00000000]
```

Collect LG Smart TV's digital evidences

#	User's Action	Path
3	External Storage History	/mmcbk0p52/cryptofs/data/db8/mediadb/media/*_log
8	Recently Service Usage History	/mmcbk0p52/cryptofs/data/db8/mediadb/media/*_log

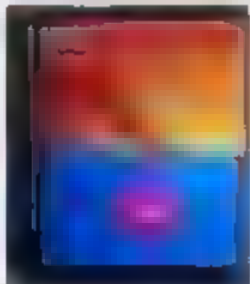
```
/tmp/usb/cdn/cdn1/image2.jpg+000
USB: 00000000000000000000000000000000
cdn: 00000000000000000000000000000000
K33W0000000000000000000000000000
/tmp/usb/cdn/cdn1/K33W0000000000000000000000000000
```

Check Serial Number on my Mac

Collect LG Smart TV's digital evidences

#	User's Action	Path
3	External Storage History	/mmcbllk0p52/cryptofs/data/db8/mediadb/media/*_log
8	Recently Service Usage History	/mmcbllk0p52/cryptofs/data/db8/mediadb/media/*_log

vcom.webos.app.connectionwizard? 연결/usr/palm/applications/com.webos.app.connectionwizard/
 assets/hd1080/deviceconnector splash.pngKLWL2fAayzc|
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Compare LG with Samsung Smart TV's Digital Evidences

Compare LG with Samsung Smart TV's Digital Evidences

	LG Smart TV		Samsung Smart TV	
	Our Research	(Sutherland [2])	Prosser [3]	Van Oort [4]
	-	2014	2014	2015
	-	Australian digital forensics confer	KIISC*	Digital investigation
	43UH6810	42LS570T ZB, SSLA740V	UN46E58000	UE40F7000SLXXN
	2016	2012, 2013	2012	2013
	webOS 3.0	webOS 2.0	Proprietary OS	Proprietary OS
Software Vulnerability (1-day vuln)	Failed to acquire data	Software Vulnerability (1-day vuln)	Software Vulnerability (1-day vuln)	Software Vulnerability (1-day vuln)
(1) Disk Imaging (2) Diffing	Using only TV's functions(config menu, app info)	(1) Disk Imaging (2) Diffing	(It's guessed in the same way as us)	

*KIISC: Korea Institute of Information Security & Cryptology

Compare LG with Samsung Smart TV's Digital Evidences

	LG Smart TV Our research	Samsung Smart TV Research [3], [4]	
		2014	2015
	-	KIISC*	Digital investigation
	43UH6810	UN46E58000	UE40F7000SLXXN
	2016	2012	2013
	webOS 3.0	Proprietary OS	Proprietary OS
Method	Software Vulnerability (1-day vuln)	Software Vulnerability (1-day vuln)	Software Vulnerability (1-day vuln)
Procedure	(1) Disk imaging (2) Diffing	(1) Disk Imaging (2) Diffing	(It's guessed in the same way as us)

*KIISC: Korea Institute of Information Security & Cryptology

Compare LG with Samsung Smart TV's Digital Evidences

User's Actions about features of TV

O Discover the user's action on the TV

X Not discover user's action or not exist on the TV

User's Action	LG Smart TV	Samsung Smart TV	
	Our research	Working [1]	Product [2]
Last TV On Time	O	O	X
TV Channel List	O	O	O
External Storage Usage History	O	O	O

Compare LG with Samsung Smart TV's Digital Evidences

User's Actions about applications

O Discover the user's action on the TV

X Not discover user's action or not exist on the TV

User's Action	LG Smart TV	Samsung Smart TV	
	Our Research	Existing (1)	Proposed (2)
Installed App Information	O	O	O
Internet History	O	O	O
Recently Service Usage History	O	O	O
Checking captured images	O	X (There's no capture func)	X (There's no capture func)

Compare LG with Samsung Smart TV's Digital Evidences

User's Actions about system configuration

O Discover the user's action on the TV

X Not discover user's action or not exist on the TV

	LG Smart TV		Samsung Smart TV	
	Our research		Existing [1]	Product [2]
Connected Wifi Information	O		O	X

Compare LG with Samsung Smart TV's Digital Evidences

User's Actions that exists for each Smart TV only

O Discover the user's action on the TV

X Not discover user's action or not exist on the TV

	LG Smart TV	Samsung Smart TV	
	Our Research	Working (1)	A. Boxes (2)
TV ON/OFF Reservation	O	X	X
Hardware Connection Information	O	X	X
Last time app opened	O	X	X
App Install History	O	X	X
Latest Watched TV Channel	X	O	X
Camera Usage	X (There's no camera)	O	X
Log policy configuration file	X	O	X
Request information in the cloud app	X (There's no cloud app)	X (Maybe there's no cloud app)	O

Conclusion

Conclusion

- **Data Acquisition by obtaining root privilege**
- **Analyze data pre-imaging, testing, and post-Imaging comparisons**
 - **Features of TV : 5 user's actions**
 - **Pre-installed applications : 6 user's actions**
 - **System configuration : 1 user's action**
- **Comparison of LG and Samsung Smart TV**
 - **Because physical methods are laborious, data acquisition in a logical way**
 - **The large classification of user's actions is similar**
 - **User's Actions have different depths**
 - **Physical characteristics of Smart TV, such as camera presence**
 - **Similar functionalities of are implemented differently**

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Q&A

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